Tropical Cyclone Outflow Patterns and Intensity Change

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Introduction/Background

Based on Masters thesis results of Spratt (1990)

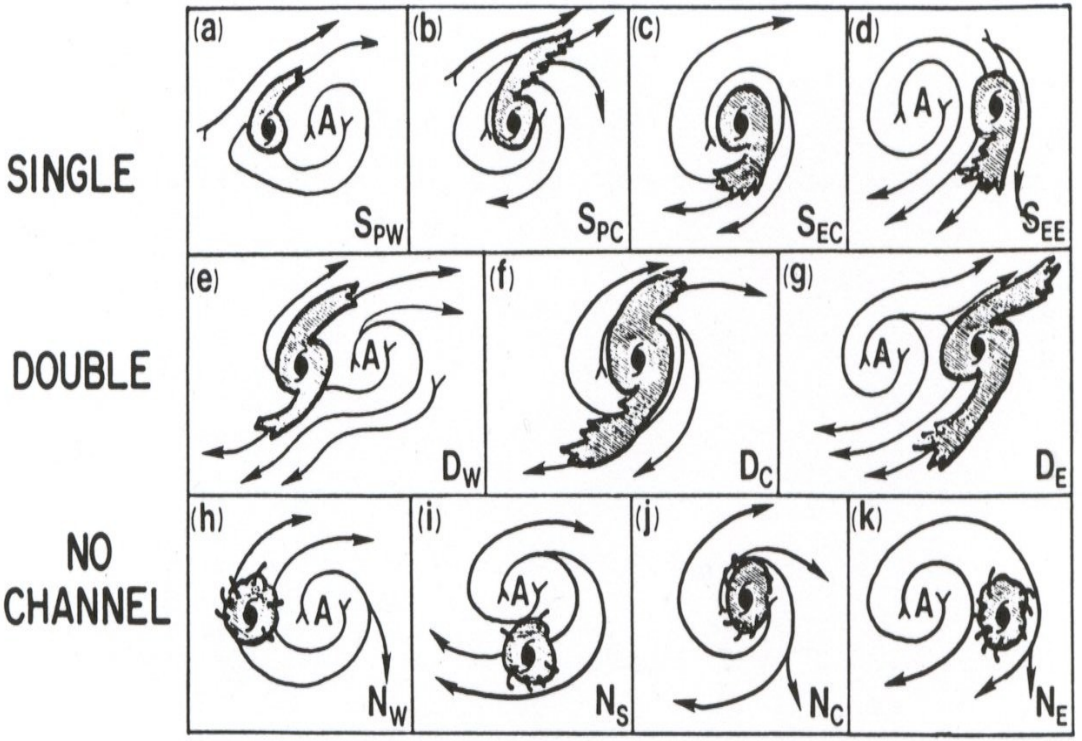
- An observational study of western north Pacific tropical cyclones:
  - 112 storms from 1979 to 1985 (0 - 40N, 110-150E)
  - JTWC best track data (from ATCR's)
  - GMS satellite mosaics of western Pacific
  - NMC 250 mb Streamline Analysis

- **Chen & Gray (1985):** identified several environmental patterns most conducive to TC intensity change.
- Builds upon Chen & Gray's work by further relating upper level outflow patterns to TC intensification.
- Emphasis on improved understanding of rapid intensification associated with the TUTT.

Upper Level Outflow Patterns: Chen and Gray (1985)

- Cloud pattern types are classified by the cirrus outflow orientation relative to the TC center:

  Single Polar (SP)
  Single Equatorial (SE)
  Double Channel (D)
  Non-Channel (N)



- Further categorized by the location of the TC center relative to its associated upper level anticyclone.

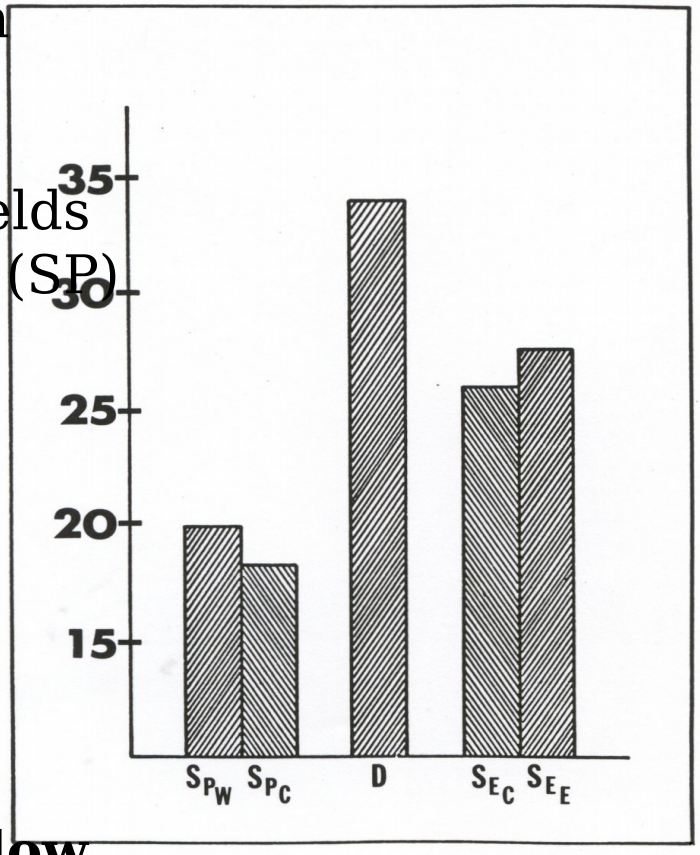
Outflow Patterns and associated Intensity Change: Chen and Gray (1985)

Double channel outflow is associated with
e fastest intensification rates.

On average, equatorward (SE) outflow yields
reater intensification rates than poleward (SP)
tflow.

No statistics are given for non-channel
ses. The observed rapid intensification
some TCs were not accounted for in
eir study (e.g. Supertyphoon Vera: from
to 140 kts in 48 hours)

**onclusion: Only distinct, vigorous outflow
sults in large rates of intensification.**



Average wind speed increase (knots) per 24 hours.

Cloud Pattern Type Additions/Changes Spratt (1990)

Eastward Cloud Pattern (E*)

- This fifth category was added due to the unique cloud patterns which developed during TC/TUTT interactions.

- Clouds generally emanate far eastward and correspond to strong, narrow bands of westerly flow extending south of TUTT systems located to the north or northeast of TC centers.

- Sometimes accompanied by equatorward outflow, indicated by long cirrus plumes extending southwestward.

- Thus, Chen and Gray (1985) erroneously included these systems in their single-channel equatorward category (SP).

Uniform cloud pattern (U)

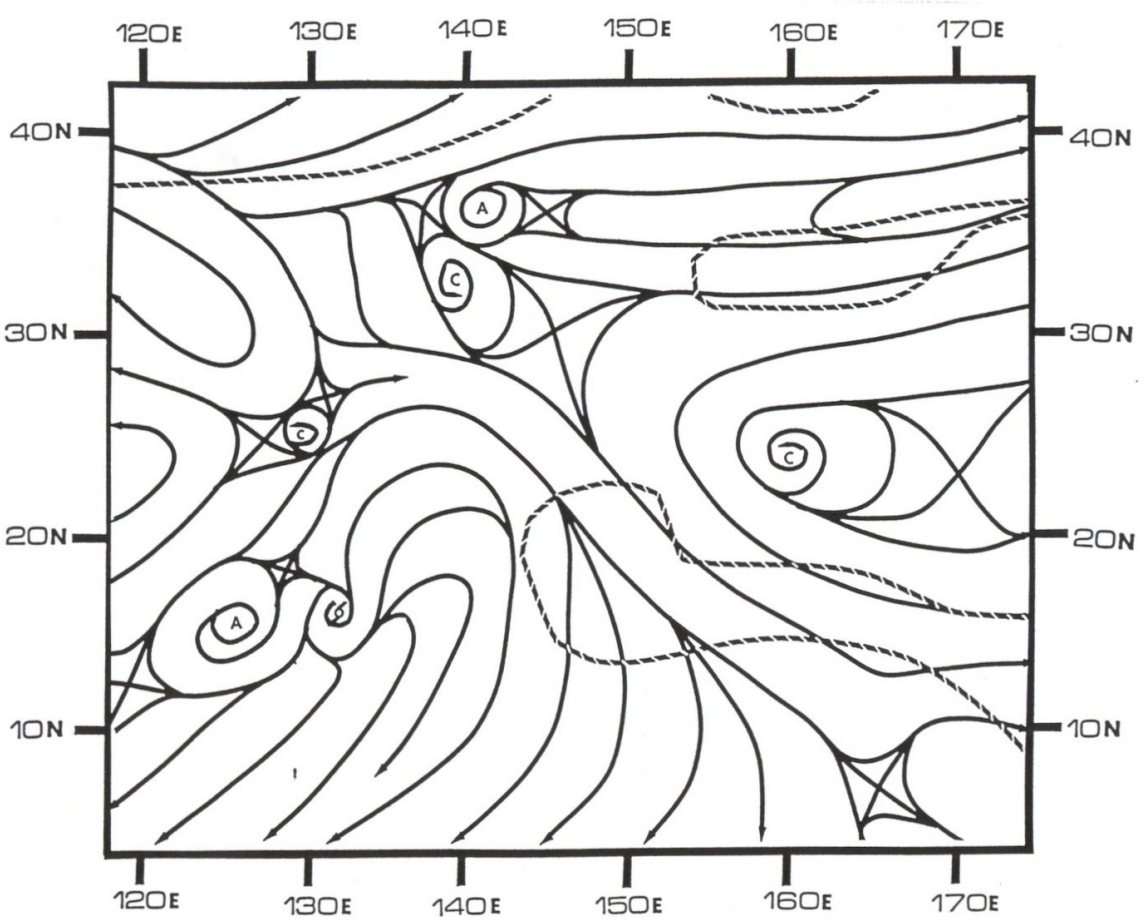
- Replaces the Non-Channel category
- Characterized by strong, symmetric upper level divergence (CDO patterns in satellite imagery)

Supertyphoon Abby (1983)
Eastward Outflow Pattern

- Explosively intensified from 75 to 135 knots in 24 hours while displaying this upper level flow pattern.

- Note the equatorward outflow in addition to the flow extending far eastward, south of the TUTT. This is common for the E* pattern.

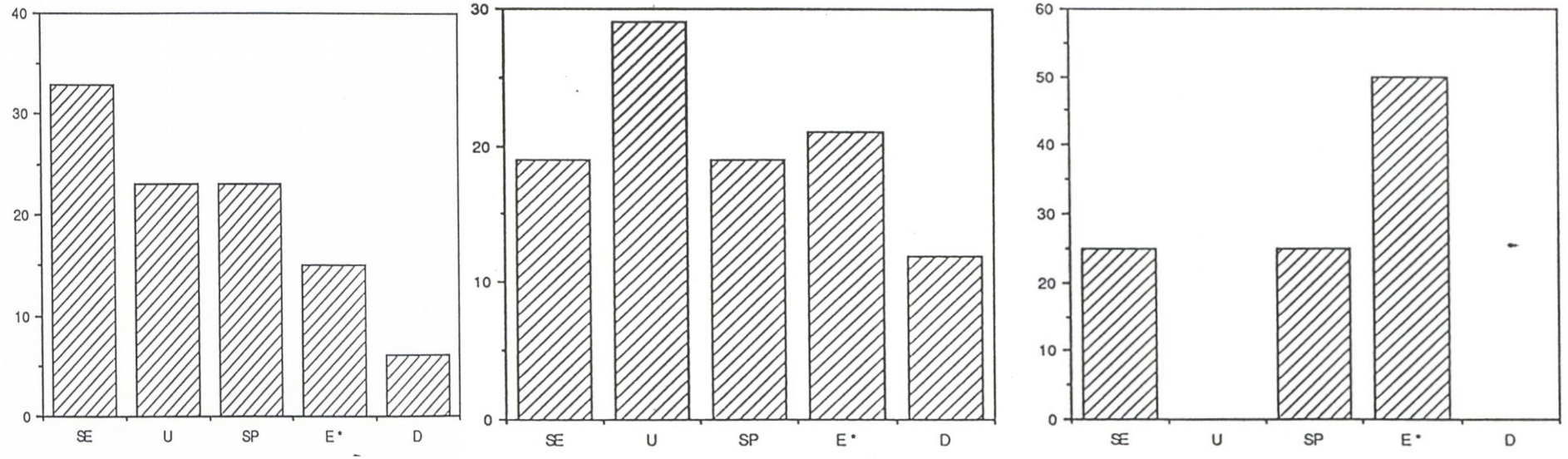
- Similar patterns



08-Aug-83 (12 UTC) 250 mb streamline analysis (solid line
Isotachs (dashed lines) are contoured at 40 knot intervals.

Relative Frequency of TC Cloud Pattern displayed during Intensification

ALL 112 SYSTEMS **"RAPID" - 42 SYSTEMS** **"EXPLOSIVE" - 12 SYSTEMS**

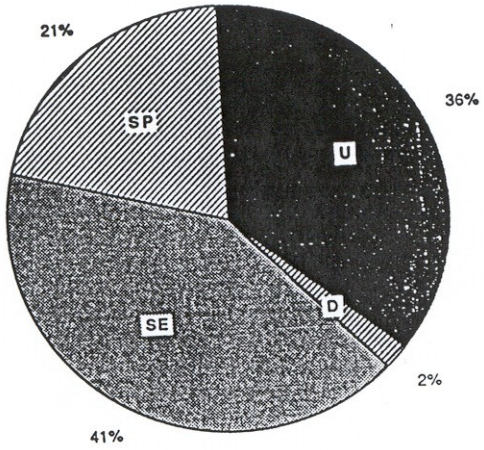


- <u>All Systems</u> - Equatorward Outflow most prevalent.

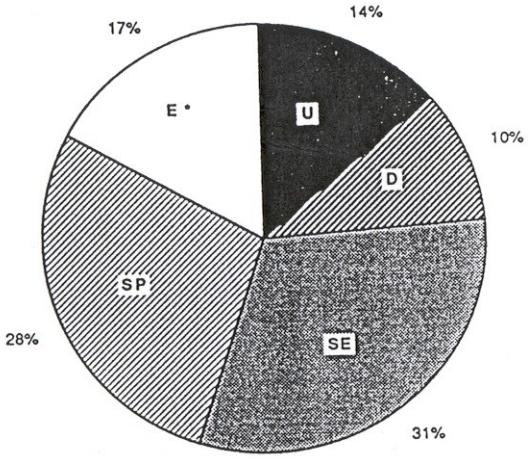
- <u>Rapid Intensification</u> (at least 15 mb/12 hr drop in central pressure)
  Uniform pattern (U) most frequent. E* pattern becomes relatively more frequent

- <u>Explosive Intensification</u> (at least 30 mb/12 hr drop in central pressure)

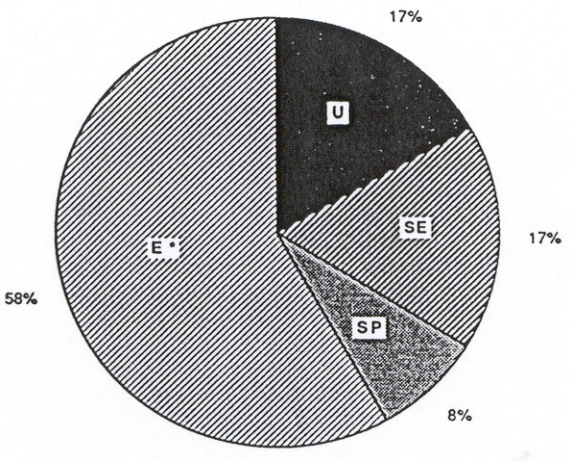
Relative Frequency of Cloud Pattern displayed during Intensification



TROPICAL STORMS (42)



TYPHOONS (58)



SUPERTYPHOONS (12)

Grouped by the ultimate intensity obtained by tropical cyclone.

The greater intensity that a TC attains, the Eastward (E*) pattern becomes more frequently observed during intensification.

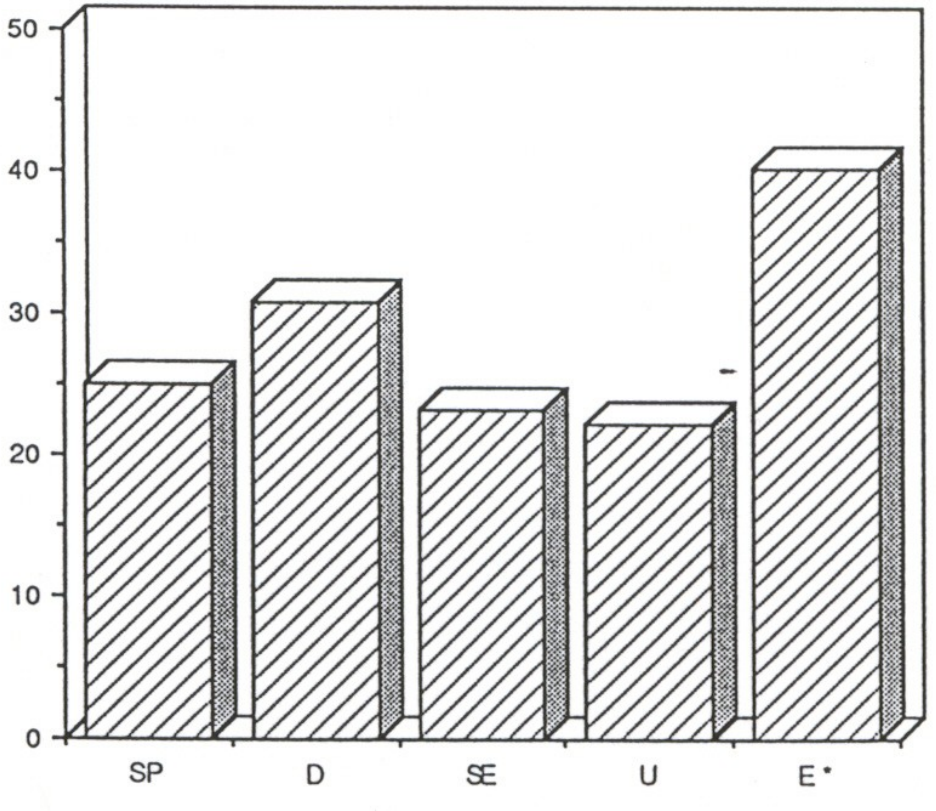
Double Channel outflow patterns were never observed for supertypho

Average Intensification Rates for Cloud Pattern Types

- On average, TCs displaying the E* cloud pattern intensified at a greater rate than TCs exhibiting the other four cloud patterns (SP,SE,D,U).

- Two-sample t-tests reveal a significant difference at the 95% confidence level between E* and each of the other patterns.

- No significant difference was found among the remaining cloud patterns.



Average maximum wind increases associated with individual cloud patterns (knots per 24 ho

Summary of TC/TUTT Interactions: Eastward Cloud Patterns (E*)

- Eastward oriented cloud patterns coincide with the most rapid intensification.

- Most prevalent in a compact region northwest of Guam, where supertyphoons typically reach maximum intensity.

- East/West oriented TUTT systems located far to the north or northeast of this region allows TC outflow to link-up with this flow and intensify rapidly. *Note: Upper cells at close proximity to TC outflow did not significantly affect intensification for any storms in this study.*

Summary of Uniform Cloud Pattern/Intensification Relationship

- Typically occurs in low latitudes equatorward of the SER within monsoon trough.

- Characterized by a large radius of unrestricted, omni-directional, uniform outflow.

- Continuation over a significant time period often coincides with periods of enhanced intensification.

- Lack of distinct single or multi-channel outflow observed during rapid intensification contradicts conventional outflow theory.

Summary of Remaining Cloud Pattern/Intensification Relationships

rd Outflow (SP)

ts from interaction with mid-latitude troughs, thus occurs at higher lati
cterized by narrow, vigorous outflow to the westerlies.
individual cases intensified rapidly, composites indicate otherwise.
s of lower SSTs and wind shear in higher latitudes may counterbalance
s of outflow channels thus preventing or slowing intensification.

Channel (D)

ar to SP pattern, but occurs at a slightly lower latitude, on average.
observed to explosively intensify or reach supertyphoon intensity, con
n and Gray's (1985) findings.

rward (SE)

e in that satellite imagery (NE flow) often contradicted the 250 mb str
sis (Easterly flow), which had no evidence of significant outflow channe

References

n, L. and W. M. Gray, 1985: Global view of the upper-level outflow patter
ociated with tropical cyclone intensity change during FGGE. Dept. of At
. Paper No. 392, Colo. State Univ., Ft. Collins, CO, 126 pp.

tt, S., 1990: Tropical Cyclone Cloud Patterns: Climatology and relations
nsity change. Masters Thesis, University of Hawaii, Honolulu, HI, 109 pp